



U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: INSTALLATION OF ELECTRONIC
DISPLAY INSTRUMENT SYSTEMS
IN PART 23 AIRPLANES

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Change:

1. PURPOSE. This advisory circular (AC) provides an acceptable means, but not the only means, of showing compliance with the Federal Aviation Regulations (FAR), applicable to the installation of electronic display instrument systems in part 23 airplanes. This material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. RELATED REGULATIONS AND DOCUMENTS.

a. Regulations. These acceptable means of compliance refer to applicable FAR sections of part 23. They may be used in showing compliance with the corresponding sections of the former Civil Air Regulations (CAR) in the case of airplanes where the CAR regulations are applicable. For convenience, the part 3 section reference is shown in parenthesis following the part 23 section reference:

§ 23.771 (3.381)	Pilot compartment
§ 23.773 (3.382)	Pilot compartment view
§ 23.777 (3.3841)	Cockpit controls
§ 23.901 (3.411)	Powerplant: Installation
§ 23.1301 (3.651 and 3.652)	Equipment: Function and installation
§ 23.1303 (3.655(a))	Flight and navigation instruments
§ 23.1305 (3.655(b))	Powerplant instruments
§ 23.1309	Equipment, systems, and installations
§ 23.1311	Electronic display instrument systems
§ 23.1321 (3.661 and 3.662)	Instrument: Arrangement and visibility
§ 23.1322	Warning, caution, and advisory lights

- § 23.1323 (3.663) Airspeed indicating system
- § 23.1331 (3.668) Instruments using a power supply
- § 23.1335 (3.669) Flight director systems
- § 23.1351 (3.681, Electrical Systems and
3.682, and 3.685) Equipment: General
- § 23.1357 (3.690, Circuit protective devices
3.691, and 3.692)
- § 23.1365 (3.693) Electric cables and equipment
- § 23.1367 (3.694 Switches
and 3.695)
- § 23.1381 (3.696 Instrument lights
and 3.697)
- § 23.1431 (3.721) Electronic equipment
- § 23.1501 (3.735 Operating Limitation and Information:
and 3.737) General
- § 23.1529 Instructions for Continued Airworthiness
- § 23.1541 (3.755) Markings and Placards: General
- § 23.1543 (3.756) Instrument markings: General
- § 23.1545 (3.757) Airspeed indicator
- § 23.1549 (3.759) Powerplant instruments
- § 23.1551 (3.760) Oil quantity indicator
- § 23.1553 (3.761) Fuel quantity indicator
- § 23.1555 (3.762) Control markings
- § 23.1581 (3.777) Airplane Flight Manual and
Approved Manual Material: General
- § 23.1583 (3.761 Operating limitations
and 3.778)
- § 91.205 Powered civil aircraft with standard
category U.S. airworthiness certificates:
Instrument and equipment requirements

- § 135.149 Equipment requirements: General
- § 135.159 Equipment requirements: Carrying passengers under VFR at night or under VFR over-the-top conditions
- § 135.163 Equipment requirements: Aircraft carrying passengers under IFR

b. Advisory Circulars. The advisory circulars listed below can be obtained from the U.S. Department of Transportation, General Services Section, M-443.2, Washington, D.C. 20590:

- AC 20-88A Guidelines on the Marking of Aircraft Powerplant Instruments (Displays)
- AC 21-16C Radio Technical Commission for Aeronautics Document No. DO-160C
- AC 20-115B RTCA, Inc., Document RTCA/DO-178B
- AC 20-136 Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning
- AC 23.1309-1A Equipment, Systems, and Installations in Part 23 Airplanes
- AC 23-8A Flight Test Guide for Certification of Part 23 Airplanes
- AC 25-11 Transport Category Airplane Electronic Display Systems

c. Technical Standard Orders. The Technical Standard Order listed below can be obtained from the Federal Aviation Administration, Aircraft Certification Service, Aircraft Engineering Division, Technical Analysis Branch (AIR-120), 800 Independence Avenue, SW, Washington D.C. 20591:

- TSO-C113 Airborne Multipurpose Electronic Displays

d. Industry Documents. These documents are an excellent resource material for additional information, guidance, and/or standards.

(1) The RTCA documents listed below are available from the RTCA, Inc., 1140 Connecticut Avenue, NW, Suite 1020, Washington, D.C. 20036:

RTCA/DO-160C Environmental Conditions and Test
Procedures for Airborne Equipment

RTCA/DO-178A/B Software Consideration in Airborne
Systems and Equipment Certification

(2) The SAE documents listed below are available from the
Society of Automotive Engineers, Inc. (SAE), 400 Commonwealth
Drive, Warrendale, PA 15096:

ARP 268G	Location and Actuation of Flight Deck Controls for Transport
ARP 450D	Flight Deck Visual, Audible, and Tactile Signals
ARP 571C	Flight Deck Controls and Displays for Communication and Navigation Equipment for Transport Aircraft
ARP 926A	Fault/Failure Analysis Procedure
ARP 1068B	Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft
AIR 1093	Numerical, Letter & Symbol Dimensions for Aircraft Instrument Displays
ARP 1161	Crew Station Lighting -- Commercial Aircraft
ARP 1782	Photometric and Colorimetric Measurement Procedures for Airborne Direct View CRT Displays
ARP 1834	Fault/Failure Analysis for Digital Systems and Equipment
ARP 1874	Design Objectives for CRT Displays for Part 25 (Transport) Aircraft
ARP 4032	Human Engineering Considerations in the Application of Color to Electronic Aircraft Displays
ARP 4067	Design Objectives for CRT Displays for Part 23 Aircraft

ARP 4101	Flight Deck Layout and Facilities
ARP 4102	Flight Deck Panels, Controls, and Displays
ARP 4102/7	Electronic Displays
ARP 4103	Flight Deck Lighting for Commercial Transport Aircraft
ARP 4105	Nomenclature and Abbreviations for Use on the Flight Deck
ARP 4256	Design Objectives for Liquid Crystal Displays for Part 25 (Transport) Aircraft (When Approved)
ARP 4260	Photometric and Colorimetric Procedures for Airborne Direct View Flat Panel Displays (When Approved)
AS 8034	Minimum Performance Standard for Airborne Multipurpose Electronic Displays

(3) The Underwriter's Laboratories (UL) Inc. document listed below can be obtained from UL, Publication Stock, 333 Pflingsten Road, Northbrook, IL 60062:

UL1418	Implosion Protected Cathode Ray Tubes for Television Type Appliances, Third Edition Revised October 3, 1983
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3. BACKGROUND. Part 23 of FAR was amended by amendment 23-41, which became effective November 26, 1990. This amendment established airworthiness standards in § 23.1311 for the installation of electronic display instrument systems in normal, utility, acrobatic, and commuter category airplanes. Prior to amendment 23-41, most electronic display instrument systems were approved for installation in part 23 airplanes by means of special conditions.

4. APPLICABILITY. This AC is generally applicable only to the original applicant seeking issuance of type certificate (TC), amended type certificate (ATC), and supplemental type certificate (STC) for the initial approval of the new type design or a change in the type design.

5. SYSTEM DESCRIPTION. This paragraph gives a very brief description of an electronic display instrument system. It is not intended to cover all the capabilities and details of these systems.

a. General. Electronic displays are replacing the traditional electromechanical and analog instruments that provided flight and powerplant instrument functions. The major display technologies now being used are multicolor cathode-ray tubes (CRT's), liquid crystal displays (LCD's), electroluminescence, plasma, and light emitting diodes (LED). The initial electronic displays were designed to mimic the electromechanical flight and powerplant instruments. Colors, symbols, and formats were chosen to resemble the conventional instruments. Since electronic display instrument systems incorporate computer devices, they can be programmed to provide many innovative display flexibilities and features. Many improvements in human factor engineering are occurring to enhance pilot performance as electronic display instrument systems evolve.

b. Configuration. Electronic display instrument systems are installed in several configurations. Basic electronic display instrument provides only one flight or powerplant instrument function while the more sophisticated systems integrate many functions on one electronic display. One of the major design goals for these systems was the elimination of several conventional gauges, instruments, and annunciators. Recent installations show a trend toward a higher degree of integration that reduces the number of scans. With the integration of instrument functions, one primary flight display can now provide many primary functions such as attitude, heading, airspeed, and altitude. Other functions are also being included on the primary flight displays such as vertical speed, flight mode annunciators, and many types of guidance cues. Integrating more functions on displays enhances the operation of the airplane when human factors are considered; however, if there is too much information on the display, clutter could result and human performance could be degraded. As more functions are integrated on the display, the evaluation to determine pilot performance during normal modes and failure modes are more complex.

6. FLIGHT, POWERPLANT, AND NAVIGATION INSTRUMENTS.

a. Instrument Requirements. Sections 23.1303, 23.1305, 23.1311, and 23.1321 in conjunction with the applicable operating rules (parts 91 and 135 of the FAR) incorporate flight and powerplant instrument requirements for part 23 airplanes. Instruments and equipment required for flights under parts 91 and 135 may be affected by the electronic display instrument system installation. Some of these instruments or equipment are gyroscopic bank and pitch, gyroscopic direction, gyroscopic rate-of-turn, slip-skid instruments, and other approved communication and navigational equipment. Design features for electronic displays permit presenting several of these functions on one display. Under these conditions, a single failure in the

electronic display instrument system may affect more than one required instrument function. There are concerns that major common-mode failures that could be induced by software errors, lightning effect, electromagnetic interference, power transient, etc., will simultaneously affect more than one instrument function.

b. Instrument Function.

(1) When the regulations were promulgated, prior to amendment 23-41, the requirements were based on "single fault" or fail-safe concepts. A single failure would cause the loss of only one primary instrument function. Only mechanical or electromechanical instruments that functioned independently for the primary parameter displayed were envisioned; that is, flight and powerplant instruments were isolated and independent. In some cases, several other instrument functions may have been housed in a common case. With the adoption of amendment 23-41, § 23.1309 was amended to permit the approval of more advanced systems that are complex and perform critical functions. Amendment 23-41 also incorporated § 23.1311 into part 23 of the FAR which provided the requirements for electronic displays.

(2) Section 23.1311(d) states that electronic display indicators, including their system and installations, and considering other airplane systems, must be designed so that one display of information essential for continued safe flight and landing will remain available to the flight crew, without need for immediate action by any pilot for continued safe operation, after any single failure or probable combination of failures. In general, without considering specific characteristics of an airplane design, information that should be considered essential to continued safe flight and landing are attitude, airspeed, altitude, and any propulsion parameter(s) necessary for continued safe flight and landing including engine restart.

c. Flight and Propulsion Instruments.

(1) Primary and Standby Instruments. A primary instrument is an instrument that is installed to comply with the applicable regulations for the required function and provides the most pertinent information instantly and directly. As defined in § 23.1311, the primary display refers to the display of a parameter that is located in the instrument panel such that the pilot looks at it first when wanting to view this parameter. Standby instruments should be located in a position that enables the pilot(s) to monitor the instruments and that minimizes eye movement between standby instruments. Flight information from the standby instruments shall be presented with the accuracy, legibility, and

readability required for error-free control of the airplane. Also, the flight information should be sufficiently free of visual cut-off, parallax, and distortion. The required standby instruments for attitude, airspeed, and altitude may be acceptable at the copilot position if it is useable from the pilot position within minimum head movement.

(2) Attitude Instruments. For flights under IFR conditions or under VFR at night for Part 135 operations, attitude information is required. The loss of or the presentation of misleading attitude could result in conditions where the pilot could not continue safe flight and landing of the airplane. Because a single failure could result in the complete loss of attitude information, attitude shall be presented by another independent (standby) attitude instrument. The standby attitude instrument should be powered from a source that is independent of the source for the primary attitude instrument and should function independently from the primary attitude instrument. This source should be installed so that it is operative for at least 30 minutes by manual or automatic selection after total failure of a single primary source.

(3) Heading Instruments. The loss of heading information could result in reduced capability of the pilot to cope with adverse operating conditions. Heading information should be provided by at least two independent instruments. For flights under IFR conditions, the gyroscopic direction instrument is considered the primary heading instrument; and the magnetic direction indicator, a self-contained heading system, is acceptable as one of the independent sources.

(4) Altitude, Airspeed, and Magnetic Compass Instruments. When the requirements of § 23.1303 (a), (b), and (c) were adopted into CAR 3 and part 23, it was envisioned that airspeed, altitude, and magnetic compass information remain available to the pilot upon the loss of the airplane's primary electrical power since these functions were provided by pneumatically driven instruments. The airplane's primary electrical power is considered the airplane's electrical generating system and the airplane's battery that is not dedicated to these instruments. Primary altimeter or airspeed instruments that require electrical power are acceptable if means are provided for their continued operation upon loss of the airplane's primary electrical power, or if pneumatically driven instruments are available for the pilot's use. Primary airspeed and altitude may be acceptable within the electronic display providing the basic T-relationship of the instrument's arrangement of § 23.1321 is retained. If primary airspeed and altitude are accepted within the display, the standby instruments would not have to be arranged in the basic T-configuration but the instruments must be useable.

(5) Rate-of-Turn Instrument. When the rate-of-turn information is displayed on an independent instrument from the primary attitude information, a secondary rate-of-turn instrument should not be necessary. When the rate-of-turn information is displayed on the same primary electronic display with the attitude information and the rate-of-turn information is not displayed continuously, a secondary rate-of-turn instrument is required. An equivalent level of safety finding may be necessary for not installing an independent rate-of-turn instrument if the primary electronic display instrument integrates both the attitude and rate-of-turn functions. In accordance with §§ 91.205 and 135.159, a rate-of-turn instrument is not required if a third attitude instrument is installed with the instrument requirements presented in § 121.305(j).

(6) Slip-Skid Instrument. The slip-skid information should be provided in all operational modes and located near the rate-of-turn instrument.

(7) Electronic Displays of Propulsion System Parameters

(i) Propulsion system parameters should be arranged and isolated from each other if practical so that any failure or malfunction that affects the display or accuracy of any propulsion system parameter for one engine should not cause the loss of display for the remaining engines or adversely affect the accuracy of any parameter for the remaining engines.

(ii) For any propulsion parameter display system, no single failure, or malfunction, or probable combinations of failures, unless it has shown to be extremely improbable, should result in the loss of display or in the misleading display of any propulsion parameter(s) that would jeopardize the continued safe operation of the airplane.

(iii) Propulsion system parameters that are not displayed continuously should be displayed automatically when any operating limit is reached or exceeded. The required displays and alerts for each phase of flight and airplane configuration should be provided in a timely manner and in a form that enables the flight crew to identify and carry out necessary remedial actions.

(iv) Propulsion system parameters necessary for the pilot to continue safe flight and landing, including engine restart, should be available to the pilot in the normal mode of operation after loss of the airplane's primary electrical power.

(8) Electronic Checklist. For those airplanes with FAA approved Airplane Flight Manual (AFM) or with a Pilot's Operating Handbook (POH), which fulfill the requirements of an AFM, if an

electronic checklist is installed, it must be approved. Policy and guidance on electronic checklist displays are contained in AC 23-8A, Flight Test Guide for Certification of Part 23 Airplanes.

7. AIRWORTHINESS CONSIDERATIONS.

a. General Criteria. Evaluations for the electronic display instrument system should consider airworthiness regulations and recommended practices and standards from industry documents as listed in paragraph 2. SAE Aerospace Standard AS-8034, "Minimum Performance Standard for Airborne Multipurpose Electronic Displays"; SAE Aerospace Recommended Practice (ARP) 4067, "Design Objectives for Electronic Displays for Part 23 Aircraft"; SAE ARP 1068B, "Flight Deck Instrumentation, Display Criteria and Associated Controls for Transport Aircraft"; and other documents listed in paragraph 2 may be used as guidelines for evaluating the visual performance parameters of the electronic displays relative to viewing, photocolormetric, luminance characteristics, etc. The certification basis should include §§ 23.1309 and 23.1311 as amended by amendment 23-41 of part 23 of the FAR.

(1) Controls and Displays. Controls and display should be clearly visible to and useable by the pilot with the least practicable deviation from the normal position and from the line of vision when the pilot is looking forward along the flight path. Controls should have an appropriate amount of tactile feel so that they can be changed without undue concentration and minimize the potential for inadvertent changes.

(2) Location of Displays.

(i) On those airplanes where the certification basis includes § 23.1321, amendment 23-14, effective December 20, 1973, the required basic T-configuration must be retained. For this application, the basic T-configuration is defined as that arrangement where the airspeed and altitude instruments are respectively centered directly to the left and right of the attitude instrument, with the direction indicator directly below the attitude instrument. Deviations from the basic T-configuration are acceptable if the droop angle is 15° or less or when the elevated angle is 10° or less. These angles are measured from a horizontal line which passes through the center of the attitude reference display and the lines passing through the center of the airspeed and altitude displays.

(ii) Deviations within the limits of +10°, -15° could be approved by an equivalent level of safety finding because these limits have been substantiated based on satisfactory service experience and/or research. Flight instrument arrangements having deviations greater than +10°, -15° and/or deviations in the vertical alignment would require an equivalent level of safety finding, which would include human factors substantiation along with a complete instrument installation evaluation considering: (1) the

total instrument arrangement and its alignment to the normal line of the pilot's vision; (2) cockpit view; (3) the integration of other functions within the instruments; (4) the information presented, format, symbology, etc., within the instrument; and (5) the ease of controlling the instruments. This evaluation should consider the different types of operation under which the airplane may be operated as defined by § 23.1559(b).

(3) Failure Isolation. Any probable failure of the electronic display instrument system should not degrade the normal operation of other required equipment connected to it or cause a flight hazard. Likewise, the failure of other equipment should not result in failure or degraded performance of the electronic display. Advisory Circular 23.1309-1A, "Equipment, Systems, and Installations in Part 23 Airplanes," provides guidance for § 23.1309(a) when using analysis by single-fault or fail-safe concepts and experience based on service-proven designs and engineering judgment. SAE documents listed in paragraph 2 of this AC provide acceptable fault and failure analysis procedures.

(4) Design Safety Assessments. Certification of electronic display instrument systems may involve new and complex technology that may not have traditional service-proven design concepts; therefore, technically qualified judgment is enhanced when the quantitative analysis is included. Although quantitative analysis is not required for certification under part 23, the applicant, at his option, may apply quantitative analysis procedures to support his design. Design safety assessment methods are also described in AC 23.1309-1A for identifying and classifying each failure condition and choosing the method(s) of safety assessment.

(5) Environmental and Atmospheric Conditions. Systems and installations should be evaluated against the effects of High Intensity Radiated Fields (HIRF) and other electromagnetic interference and atmospheric conditions such as the indirect effects of lightning.

(i) Section 23.1309(e) contains the regulatory requirements for the protection of aircraft electrical/electronic systems against the indirect effects of lightning. These requirements are applicable for electrical/electronic systems performing critical and essential functions. For guidance, Advisory Circular 20-136, "Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning" dated March 5, 1990, and RTCA/DO-160C, section 22, "Lightning Induced Transient Susceptibility," dated June 19, 1992, or later revisions thereto, provide acceptable methods and procedures for determining compliance with these requirements.

Advisory Circular 20-136 provides guidance to verify the protection of systems installed in an aircraft while section 22 of RTCA/DO-160C provides methods to qualify equipment prior to installation in an aircraft.

(ii) For the protection of aircraft electrical/electronic systems against High Intensity Radiated Fields (HIRF), the interim policy guidelines should continue to be used. These guidelines are contained in AIR-100's memorandums dated December 5, 1989; January 30, 1990; March 8, 1991; November 1, 1991; July 29, 1992; and subsequent memorandums. These memorandums state that special conditions must be issued for systems that perform critical functions until the HIRF requirements are incorporated in parts 23, 25, 27, and 29 of the Federal Aviation Regulations (FAR). The words "radio frequency energy" in § 23.1309(e) are not intended to include HIRF.

(6) Temperature/Pressure Conditions.

(i) The equipment temperature/pressure limits established by the manufacturer should not be exceeded by the maximum temperature/altitude of the operating environment of the airplane. Evaluation of the equipment installation should consider the maximum operating altitude of the airplane and whether the equipment is located within a temperature and/or pressure-controlled area. Applicable methods for testing the performance characteristics of the equipment for specified temperatures and altitudes are provided in RTCA/DO-160C. Test and/or analysis ensures the compatibility between the operational environment and the environmental equipment category of the laboratory tests.

(ii) Electronic systems reliability is strongly related to the temperature of the solid-state components in the system. Component temperatures are dependent on internal thermal design and/or external cooling. In evaluating the temperature environment, consideration should be given to the additional heat generated by the equipment especially in a location where airflow is restricted. For determining if adequate cooling is provided, the evaluation should make maximum use of previous data with comparable installations thus limiting ground and/or flight tests to those installations which cannot be verified conveniently by other means. When the equipment operating environment cannot be verified from previous experience or from an evaluation of temperature values in that equipment location, a cooling test should be conducted.

(iii) Attitude information should continue to be presented for a minimum of 30 minutes after the in-flight loss of cooling for the primary instrument when operating in the normal operating environment (temperature/altitude). If proper performance of the flight instrument function(s) is adversely affected due to in-flight loss of cooling, such failure conditions should be annunciated. Pilot subsequent actions should be

documented in the Airplane Flight Manual (AFM) or on placards. Automatic over-temperature shutdown of the system should be considered a failure condition.

(iv) Annunciation of in-flight loss of cooling or fan monitors may not be required if it is shown by a safety analysis or test demonstration that a hazardous failure condition does not occur. The safety analysis should consider the reliability of the fans, redundancies of the functions, reversionary features (such as the ability to transfer critical functions), the annunciation of over-temperature and its response time, and the availability of other flight instrumentation. In some systems, cooling fans may only be installed to extend the life of the components and not to prevent a failure condition or shutdown of the equipment. These types of installations do not require fan monitors or temperature sensors. If the cooling fans are needed to prevent a hazardous failure condition, fan monitors should be installed or there should be another method to determine the status of the cooling fan during preflight checks.

(7) Software Consideration. Software assessment is appropriate for the functional hazard assessments, but it is not directly applicable to quantitative analysis. Probability analysis does not yield results in which confidence can be placed for determining the number or kinds of software errors, if any, that may remain after the completion of system design, development, and test. One means of obtaining approval for software is by using the methods contained in RTCA/DO-178A/B, Software Consideration in Airborne Systems and Equipment Certification. These documents or subsequent revisions provide acceptable means for assessing and controlling the software used to program digital computer-based systems. The purpose of these documents is to identify objectives and describe acceptable techniques and methods for the development and management of software for airborne digital systems and equipment.

(8) Electromagnetic Interference. The electronic display instrument system should not be the source of objectionable conducted or radiated interference nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the airplane.

(9) Aircraft Electrical Power Source.

(i) The electronic display instrument system should be installed so that it receives electrical power from a bus that provides maximum reliability of operation without jeopardizing other essential or critical electrical loads connected to that bus. Means should be provided to indicate when adequate power is available for proper operation of the instrument.

(ii) Advanced systems with microprocessors and its software stored in memory to control functions have made these systems more sensitive to momentary power interruptions. Techniques should be used to reduce the momentary power interruptions or the equipment should be designed so that momentary power interruptions will not adversely affect the availability of essential information required for continued safe flight and landing. The category selected from RTCA/DO-160C for momentary power interruptions should be appropriate for the intended use. Momentary power interruptions less than 200 milliseconds (ms) due to load switching should not cause a significant interruption of display operation or change in display content. No pilot action should be needed to cause the system to return to normal operation following momentary power interruptions less than 200 ms. The selected values on the display should not change as a result of momentary power interruption. On multiengine airplanes, the attitude display (primary or standby) should be useable within 1 second after the momentary power interruptions due to engine failure. Large electrical loads required to restart an engine such as on turboprops and small jets should not affect the availability of essential information required for continued safe flight and landing. Hazardously misleading information should not be presented or permanent damage be inflicted on the equipment following these momentary power interruptions.

(10) Readability and Legibility.

(i) The required instrument functions should be easily readable and interpreted without confusion over the total useable display area. The display symbology should be clearly readable under all ambient illumination conditions ranging from night environment to direct sunlight through a side cockpit window or front window. The electronic display instrument system should be legible in all operating and environmental lighting conditions including direct sunlight expected in service with the brightness level adjusted at the minimum luminance level. The minimum luminance level represents the expected end-of-life value of the display or minimum acceptable output that is established by the manufacturers. The display luminance should be sufficient to provide a comfortable level of viewing with rapid adaptation when transitioning from looking outside the cockpit.

(ii) Some displays will have gradual reduction of luminance levels. As part of the continued airworthiness requirements of § 23.1529, consideration should be given for establishing a flight operational evaluation and/or feasible maintenance evaluation for the minimum luminance level appropriate for the type of display, flight deck location, method of format, symbology, color used, etc. Minimum luminance evaluations should be performed when the brightness seems questionable and at periodic inspections that have been established. Although an automatic luminance control compensation is not required, it would decrease

pilot workload. Manual luminance control should be provided for each display and should not be adversely affected by failure of the automatic luminance control.

(11) Symbology and Format. Electronic displays in the cockpit should have related symbology and format and should be consistent with their intended use. Appendix A to SAE ARP 4102/7, Electronic Displays, provides recommended symbols for Electronic Attitude Direction Indicators (EADI) or Primary Flight Display (PFD) used in the flight deck of transport aircraft.

(i) Symbols should not have shapes that are ambiguous or could be confused with the meaning of some similar symbol. The type and function of symbology should be clearly defined and appropriately classified for pilot understanding. The symbology should be examined for characteristics in which incorrect information could be presented. Symbols representing the same functions on more than one display should have the same shape and color. Different types of symbols and format among instruments may be acceptable providing a human factor analysis finds them not hazarding misleading. For indicating bank angle on the attitude displays in the cockpit, the type of pointer ground (fix) or sky (moveable) should be similar for ease of interpretation.

(ii) Powerful formats are possible with an electronic display system, but too much information could result in clutter and will reduce the efficiency of the pilot cues. Density of the information on the display should be compatible with the pilot's ability to recognize essential information and to minimize misinterpretation. Symbols and markings that are displayed during specific phases of flight may be removed at other times to reduce clutter. Consideration should be given to the minimum display size for suitable readability. In the reversionary or compacted modes, when combining essential information on a display after another display or unit fails, the display format should not be confusing and the information should still be useable. The reversionary or compacted mode should only be used under emergency/abnormal operating conditions. Attitude, altitude, and airspeed information on the primary electronic display should not be inhibited during these modes and the basic T-configuration should be preserved.

(iii) Presentation of airspeed, altitude, or certain propulsion parameters (as applicable) should convey to the pilot a quick-glance sense of the rate and trend of information. For airspeed and altitude, digital only readout should not be approved on the primary display or on the standby instruments, but it is acceptable on a display used as supplementary information. The application of digital-only readout to propulsion parameters should be made with care and subject to evaluation on a case-by-case basis.

(iv) The display of a round dial moving pointer with a digital readout has been found acceptable. To accommodate a larger operating range on a linear tape, a moving scale display has been adopted with the present value on a digital readout. Since the moving scale display does not provide any inherent visual cue of the relationship of present value to low or high airspeed limits, quick-glance awareness cues are added.

(A) Airspeed displays with moving scales must provide appropriate low speed awareness cues. The low airspeed awareness cues must include a caution cue (amber) at some multiple of the stall speed, i.e., $1.3 V_s$ and a warning cue (red) at the stall warning speed. The low airspeed awareness cues must be accurate for any airplane weight and flap configuration (usually angle-of-attack based). Also, airspeed moving scale displays should have low speed markings displayed in the lower and high speed markings at the upper part of the scale.

(B) Linear tape altimeter displays must include enhancements to denote standard 500 foot and 1000 foot increments and convey unambiguously, at-a-glance, the present altitude. The linear tape display must also include enhancements to convey information to the pilot to aid him in anticipating the level-off altitude during high rates of climb and descent, and provide effective ground awareness cues for the approach and landing phase of flight.

(v) The heading instrument should provide a clear and unmistakable display of aircraft position, heading, and track relative to the desired course/track. Pilot computation or interpretation should be minimized. On the primary display, the heading scale should have a mode that presents at least 180° of arc (270° is recommended).

(12) Annunciation.

(i) The electronic display instrument system should provide the pilot with visual discernible annunciators that will alert the pilot of improper or unsafe system operating conditions. The visual annunciators should be distinctive under all normal lighting conditions and commensurate with other cockpit warnings. Under night lighting, with the display average brightness at the lowest useable level for prolonged flight, visual annunciators should be adequately useable. The position of the annunciations should be consistent in a specific area of the electronic display to ensure proper interpretation by the pilot. When a failure occurs and/or when reversionary modes are used, an annunciation should be provided to indicate abnormal system status and the display should not provide hazardously misleading information. Annunciation that requires flight crew action should be evaluated to determine if the required actions can be accomplished in a timely manner without exceptional pilot skill.

(ii) Where multiple system configuration and more than one sensor input are available for source selection, the switching configuration by annunciation and/or by selector switch position should be readily visible, readable, and not hazardously misleading. Mode and source selection annunciators should be compatible throughout the cockpit. Cautionary annunciation methods should be consistent when numerous interface switching configurations are possible to ensure that the flight crew can properly interpret the system status.

(iii) The alerting messages should differentiate between normal and abnormal indications. Abnormal indication should be clear and unmistakable by using techniques such as different shapes, sizes, colors, flashing, boxing, outlining, etc. Individual alerts should be provided for each function that is essential for safe operation.

(13) Implosion Protection. The display unit should be designed and constructed to prevent implosion when the unit is operating over the range of normal and abnormal operating environment in the airplane. In case of an abnormal event of a display implosion, no incapacitation of the flight crew or adjacent equipment should result. The display unit shall be tested for endurance for the most severe conditions of pressure and temperature levels and variations in both normal and abnormal operating conditions (including overpressure and decompression) specified by RTCA/DO-160C. To verify the display unit performance in the event of an implosion, the unit should meet the requirements in UL-1418, listed in paragraph 2.

(14) Color Standardization.

(i) Color should be considered an enhancement for understanding the display information that leads to performance improvement. Color should be selected to minimize display interpretation; however, a proliferation of color sets can ultimately reduce safety rather than increase it. The following table depicts acceptable colors as required by § 23.1322 and other recommended colors as related to their functional meaning for electronic display instrument systems:

(A) Display features should be color coded as follows:

Warnings	Red
Flight envelope and system limits	Red
Cautions, abnormal sources	Amber/Yellow
Earth	Tan/Brown
Scales and associated figures	White
Engaged modes	Green
Sky	Cyan/Blue
ILS deviation pointer	Magenta
Flight director bar	Magenta/Green

(B) Specified display features should be allotted colors from one of the following color sets:

	<u>Color Set 1</u>	<u>Color Set 2</u>
Fixed reference symbols	White	Yellow*
Current data, values	White	Green
Armed modes	White	Cyan
Selected data, values	Green	Cyan
Selected heading	Magenta**	Cyan
Active route/flight plan	Magenta	White

*The extensive use of the color yellow for other than caution/abnormal information is discouraged.

**In color set 1, magenta is intended to be associated with those analog parameters that constitute "fly to" or "keep centered" type information.

(C) Precipitation and turbulence areas should be coded as follows:

Precipitation 0-1 mm/hr	Black
1-4 "	Green
4-12 "	Amber/Yellow
12-50 "	Red
Above 50 "	Magenta
Turbulence "	White or Magenta

(D) Background color (Gray or other shade)	Background color may be used to enhance display presentation.
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(ii) When the color assignment deviates from the above color assignment, the applicant should ensure that the chosen color assignments are not susceptible to confusion for symbol meaning and increased workload. Where appropriate, color assignment should be consistent with other color displays in the panel. Luminance difference and/or color difference should be sufficient to preclude confusion or ambiguity as to the informational content under all operating ambient illumination conditions. The specific colors should be consistent with change in brightness on the displays over the full range of ambient light conditions. Under high and low levels of lighting, the color degradation should not preclude the pilot interpreting display information.

(iii) Color is an enhancement for understanding the display information that leads to performance improvement, but it should not be the sole means of discrimination of critical information. Color degradation should be obvious and should not preclude the pilot from interpreting display information. Display should remain legible, stable, and unambiguous when operating in a degraded mode.

(iv) For warnings and cautions, § 23.1322 provides specific requirements for the assignment of red and amber for visual annunciations.

(A) A warning annunciation is for emergency operational conditions, when immediate flight crew recognition is required and when corrective or compensatory action may be required; the associated color is red. Cautionary annunciation is for abnormal operational conditions, when immediate flight crew awareness is required and subsequent flight crew action may be required; the associated color is amber. An advisory annunciation is for operational conditions, which require flight crew awareness is required and flight crew action may be required; the associated color should be white or any other unique color. For indication of safe operating conditions, the color green should be used.

(B) A complete list of warnings, cautions, and annunciation messages should be included in the AFM, supplemental AFM, and/or placards. If the manufacturer's pilot operating guide is found adequate and acceptable, it may be referenced in the AFM or supplemental AFM as a means to satisfy this requirement.

(15) Airplane Flight Manual (AFM). For each equipment required for IFR approval, the AFM or supplemental AFM should contain the limitations, and operating and emergency procedures applicable to the equipment installed. Installations limited to VFR use only may require an AFM or supplemental AFM depending upon the complexity of the installation and need to identify necessary limitation and operating procedures. Additional policy and guidance on AFM's are contained in AC 23-8A.

(16) Lag Time and Data Update. The display of information essential to the safety of flight should be thoroughly responsive and accurate to the operational requirements. The delay effects by the electronic display instrument system of essential information including attitude, airspeed, altitude, heading, and specific propulsion parameters should not degrade the pilot's ability to control the airplane. SAE ARP's provide recommended lag times for display of the format and primary flight data, and minimum rates for data updates to meet symbol motion.

(17) Test Functions. The electronic display should incorporate a pilot selectable or automatic test mode that exercises the system to a depth appropriate to the system design. Alerting and annunciation functions should be exercised that are necessary to alert the pilot of unsafe conditions.



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